ON THE HIBERNATION OF ADULT MOSQUITOS

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The investigations of which the results form the subject of this paper were carried out during the years 1920-24 in a district of North Carnarvonshire lying between the Menai Straits and the Snowdonian mountains. The purpose of the investigations was to endeavour to elucidate the habits of hibernating mosquitos and the relation of certain species of mosquito to man and to his domestic stock.

The field work involved consisted of visiting farm buildings of all types and collecting, for identification and also for use in other studies, the mosquitos seen. The insects were collected in 6-in. by 1-in. specimen tubes; the tube was brought over a resting mosquito, which on taking flight generally flew up into the tube, when it could be secured by means of a wad of cotton wool. Owing to the poor lighting of most of the buildings, the work had to be done in most cases by the light of an electric torch. For a short time a glass tube with gauze covering one end, the other being closed with a rubber 'valve' (as devised by Adie, 1911) was used; it was found that under the cool conditions in which the collecting often was carried out, moisture from the breath condensed on the inner wall of the tube in quantity sufficient to imperil the safety of the insects. It should be remarked that this type of tube has proved of great use in the laboratory as a 'cage,' since the 'valve' enables one to release mosquitos into the tube, or to remove them from it, much more easily than is the case with a tube closed with gauze at both ends.

In the investigation of such a matter as the hibernation of animals, there are two sets of factors which must especially be considered, viz., climatological factors, and environmental factors. Taking the climatological factors first, it may be said that North Carnarvonshire has a climate which is mild but somewhat wet.

The difference between the isotherm for the months of January and July is about 10° C., the former being approximately 5·5° C., and the latter a trifle over 15° C. Away from the Snowdonian mountains a severe frost or a fall of snow is uncommon, while light frosts—sufficient to freeze up road puddles—are not often experienced. It is probable that the relatively slight range of temperature explains certain differences between the results set forth here and those obtained by Sella (1920) and Grassi (1921a and 1923) among others. A temperature of 5° C. is probably less rigorous for a race of animals accustomed to a temperature of only 15° C. than for a race accustomed to something in the neighbourhood of 25° C.

The second group of factors largely resolves itself, in the present instance, into the conditions of the farm buildings and of the animals found therein. The main agricultural pursuit of the area is the grazing of sheep ; while dairy farming is carried out on a small scale, there are only two or three large dairy-farms in the district examined. On a typical farm we find up to a dozen cows, lodged probably in one shed, a few calves in another shed (a ' calf-cot '), two or three horses in their stable, and usually a dozen or more pigs in three or four styes. While practically all farmers keep fowls, it is only a few that do so on any considerable scale. The farm buildings are for the most part old, apart from the dwelling-houses, which in most cases are of far later date—the old dwelling-houses were usually part of the same range of buildings as the animal houses. In consequence of their age, the animal houses are dark, low, ill-ventilated and warm, and often difficult to keep clean. This is more especially the case with the pig-styes and calf-cots and to a lesser degree with the stables. While the other buildings have a flat ceiling—often forming the floor of a loft above—the pig-styes are almost all lean-to in construction ; about thirty inches high in front and six to eight feet high at the back ; very rarely the doorway is placed in the high side, or in the end, but it is even then no larger than will admit a large pig. There is, in consequence, a considerable space overhead in which warm air can accumulate. Except the pig-styes, which are hardly touched, the buildings are whitewashed once a year on most farms, when they get a thorough cleaning ; this usually takes place in early summer. Throughout the winter the stables and cowsheds are cleaned daily ; the other buildings are attended to less frequently or not at all.

The pig-styes generally have masses of cobwebs dependent from their ceilings.

Throughout Northern Europe only three species of mosquito are known to hibernate as the adult, viz., *Anopheles maculipennis*, *Theobaldia annulata* and *Culex pipiens*. In the autumn of 1920, when I commenced my investigations, our knowledge of the phenomena of hibernation was not far advanced from the point where Annett and Dutton left it in 1901. Thus Hindle (1914) briefly states that

> 'In cold regions mosquitos pass through the winter in the egg-stage, but in addition some of the females hibernate in dark corners.'

Patton and Cragg (1913) state that

> 'Mosquitos, like all other insects which normally have a short life-history and which can only multiply under certain conditions are able to exist . . . . during unfavourable seasons. . . . . The commonest manner in which this is brought about is by the hibernation of impregnated females, which, finding the season too advanced to complete the maturation and deposition of their ova, seek out resting places and remain concealed until favourable conditions present themselves at the commencement of the next season. During this period, which may extend to several months in temperate climates such as those of Europe, they feed seldom if at all, and remain in a passive and torpid condition, living upon the store of food material already accumulated, until they are revived by the warm weather.'

Finally, Lang (1918) only cites Annett and Dutton's work on hibernation.

Since the autumn of 1920, a number of excellent papers on the hibernation of mosquitos have appeared; to mention but a few, those of Grassi and of Sella from Italy (*op. cit. supra*), of Osterwald and Tänzer (1920) from Saxony, and probably most important of all, Wesenburg-Lund's memoir on the Danish mosquitos. There have been close approximations between the results obtained by the more Northern workers—*e.g.* Wesenburg-Lund (1921), Osterwald and Tänzer, and myself, and between the results of more Southern workers such as Sella and Grassi; as I have suggested above, a few variations, which will be pointed out in due course, are probably climatic in origin.

The three species of mosquito which have already been mentioned are found in North Carnarvonshire. In the summer the larvae are to be found in almost every ditch, *Anopheles* being particularly abundant. During the winter neither of the Culicine species are as abundant as one would expect to find them. In consequence of this,

and also because of its far greater importance from the point of view of medicine, most attention has been paid to *Anopheles*.

Roubaud has recently (1923) proposed a physiological basis for hibernation. He suggests that the hibernation is brought about, not by the increasing cold, but by an auto-intoxication of the insects by a ' renal surcharge.' He believes that the latest-hatched members of the summer generations inherit a ' patrimoine d'intoxication ' which gives rise to the peculiar physiological conditions of the hibernating female. Among others, this condition manifests itself physically by a hypertrophy of the malpighian tubules, physiologically by the fact that any blood ingested goes to form fat body, instead of assisting in the maturation of the ova. It is only when this intoxication has worked itself off, which does not happen till early spring, that the eggs develop. As far as North Wales is concerned, I have not observed either the physical or physiological signs of this intoxication ; out of numbers of mosquitos dissected during the winter months, in none did I observe any abnormal state of the malpighian tubules, while I discovered that both in the laboratory and also under natural conditions, female mosquitos matured their eggs as early as January.

Grassi (1921a) and also Sella (1920) have drawn a distinction between true or rigorous hibernation and partial hibernation. The former is defined as a condition in which the insect develops fat-body towards the late autumn, and does not then feed until spring, while in the latter stage it continues to feed and does not become fat. Grassi believes that it is the former class of females that perpetuates the species, and that the latter die off before the spring. According to Roubaud (1923) this is also the case in France. In the former state the insect does not move about. Whatever may be the conditions on the European continent, where the mosquitos are subjected to a greater variation of temperature than occurs in this country, in Carnarvonshire I found *Anopheles* flying actively within the farm buildings throughout the winter, save when the temperature fell to somewhere near zero Centigrade. The insect is willing to feed at all times except immediately after a blood meal. Yorke and Macfie, experimenting at the Liverpool School of Tropical Medicine with *Anopheles* which I had sent them from North Wales, found that a considerable number died in their incubators, apparently as the

result of the development of their eggs, which they could not deposit owing to lack of facilities. I have observed the development of eggs in wild *Theobaldia* as early as January.

Anopheles maculipennis. This species is, throughout the year, an inhabitant of farm buildings, as Roubaud (1920) and Wesenburg-Lund (1921), among others, have pointed out. During the winter females alone occur.

It occurs chiefly in the pig-styes ; next, in order of frequency, in calf-cots, cowsheds and stables—very rarely in these last. In lofts and barns it rarely occurs—never, I think, unless these are in communication with a chamber containing animals. I have only once found it in a fowl-house. Taking at random from my notes a series of twelve farms examined during the latter part of November and the first part of December, 1923, I find that I recorded it as occurring abundantly in six groups of pig-styes, and as being less abundant in four other groups. It was once recorded as abundant in cowsheds, and four times as occurring in these buildings. It was once recorded from a stable, and twice from lofts or barns. At one farm where it was absent from the pig-styes, these had been empty for at least two months, while at one farm there were no buildings other than cowsheds and their lofts. It occurred in pig-styes about five times ; if a longer series of records were to be taken, the attraction which pig-styes have for mosquitos would be even more marked.

In whatever buildings *Anopheles maculipennis* occurs, it is more abundant towards the upper parts, as was pointed out by Annett and Dutton (1901). Frequently it rests on cobwebs. As a general rule, it will be found in the more dimly-lit places, such as the sides of beams furthest from the light. As has already been stated, it feeds throughout the winter ; and at least 50 per cent. of the mosquitos collected during these investigations contained recognisable blood.

Usually the insects take up the resting-position so often described, but, as Annett and Dutton pointed out, under certain conditions, especially cold, they take up a *Culex*-like attitude. Under the influence of cold they become exceedingly torpid and when touched make no effort to fly. They rapidly recover in a warmer place, however. Normally the insects are active, flying spontaneously

both in captivity and in nature. A bright light, as well as the approach of some object, causes them to take flight; in this my experience has been different to that of Roubaud (1918) who found that a bright light caused flying mosquitos to come to rest.

The attraction which the animals' quarters have for this mosquito is probably due to several causes. I am of opinion that the insect's main desiderata are darkness, warmth, and easily-accessible food. This last condition will be fulfilled by dwelling-houses as well as animal houses, and need not be taken into consideration. In the area with which I am acquainted, it is the pig-styes which fulfil the first two conditions most completely, while the animal houses as a whole are darker, warmer and quieter than the dwelling-houses. It may be that an attraction towards the animal houses arising from these causes may be in progress of giving rise to a zoophile race of mosquitos, as has been supposed by Roubaud (1920) and by Grassi (1921b). It is possible that the comparative hairlessness of the pig, and the fact that its skin, though thick, is highly vascular—affording a readily-tapped source of blood—may be additional attractions for the insect.

The Malaria Committee for the Province of North Holland (1920) found that mosquitos were most numerous in pig-styes. On the other hand Vogel (1921), working in the zone occupied by the Fifth German Army during the late War, found that cowsheds were preferred to pig-styes.

Theobaldia annulata. This species also hibernates in the adult stage, the females alone surviving the winter. Like *Anopheles* it is an inhabitant of the animal quarters, but occurs also in the colder buildings, such as store-houses, etc., and occasionally in dwelling-houses. I think, however, that it resorts to these last only when no other buildings where food may be obtained are available. Like *Anopheles*, it feeds throughout the winter. It rests on cobwebs as a rule, on the lower part of a sloping ceiling or on the wall, and takes up the hunchback *Culex* attitude.

On 10th January, 1924, I obtained, in some cellars at the University College of North Wales, Bangor, two females of this species which contained matured eggs. They were given a blood meal, and placed in a breeding cage, where both oviposited the same

day ; the temperature of the laboratory was about 13° Centigrade. The larvae hatched out on the 21st, the maximum temperature in the interim being 14·7° C. and the minimum 6·7° C.—mean temperature about 13° C. Unfortunately, the larvae were destroyed through an accident to the breeding tank.

In 1924, both this species and *Anopheles* left the farm buildings towards the end of March, but larvae were not found till mid-May.

Culex pipiens. Unlike the two previously-mentioned species, *Culex* hibernates almost exclusively in cellars, lofts and similar cool places. It is a more lethargic insect than the other two, spending most of its time resting on the walls and on cobwebs ; it is found towards the lower part of the walls. When disturbed it flies actively. This species is supposed to be more partial to avian blood than to mammalian. I have only rarely taken specimens containing blood, and, unfortunately, on those occasions I have had no facilities for determining the nature of the blood, whether mammalian or avian. In the laboratory this species will not feed on man in my experience.

During 1923-24 my attention was directed, in addition to the main investigation, towards the possibility of reducing the number of *Anopheles* in a district, by the collection or destruction of the hibernating adults. One farm was particularly well-adapted for investigations of this nature, since the breeding-place of the mosquitos found in it was known to be a small pond actually within the farm-yard, and there were no other places near-by—either hibernating quarters or breeding-places—from which an influx of mosquitos might be expected. All mosquitos seen were collected—many hundred *Anopheles* and a few *Culex* and *Theobaldia.* In the course of this work it was found that if a building, *e.g.*, a pig-stye, was apparently cleared of mosquitos one day, more would be found there the next. Having regard to the construction of the buildings, I am inclined to interpret this as being due to emergence of mosquitos from recesses in which they could not be detected, rather than to an actual migration ; a certain amount of migration between adjoining buildings undoubtedly takes place, when there are any direct communications such as holes in the walls. Buildings were apparently cleared by several collections.

Despite the collecting, *Anopheles, Theobaldia* and *Culex* appeared

in these breeding-places in early summer, and were abundant in the buildings, and I am forced to the conclusion that the collection of hibernating mosquitos is by itself of no value as a means of control

SUMMARY

1. *Anopheles maculipennis*, *Theobaldia annulata* and *Culex pipiens* hibernate as adult females.

2. *Anopheles maculipennis* occurs in those farm buildings which contain animals, especially in pig-styes ; it occurs also in calf-cots, cowsheds and stables, and, very occasionally, in lofts or barns. When these communicate with a building containing animals, the anopheline flies spontaneously at any time of day. It feeds throughout the winter. Under laboratory conditions, the females will develop eggs during the winter, if kept at a sufficiently high temperature.

3. *Theobaldia annulata* occurs in the same type of building as does *Anopheles* and also in cooler places such as lofts and cellars. Like *Anopheles*, it feeds throughout the winter and flies spontaneously. Females which contain matured eggs have been caught in January.

4. *Culex pipiens* occurs in cool buildings and cellars exclusively. It is much less active than the other two species.

5. Experiments to determine the effect of collecting the hibernating females have shown that this alone is not a useful means of control.

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